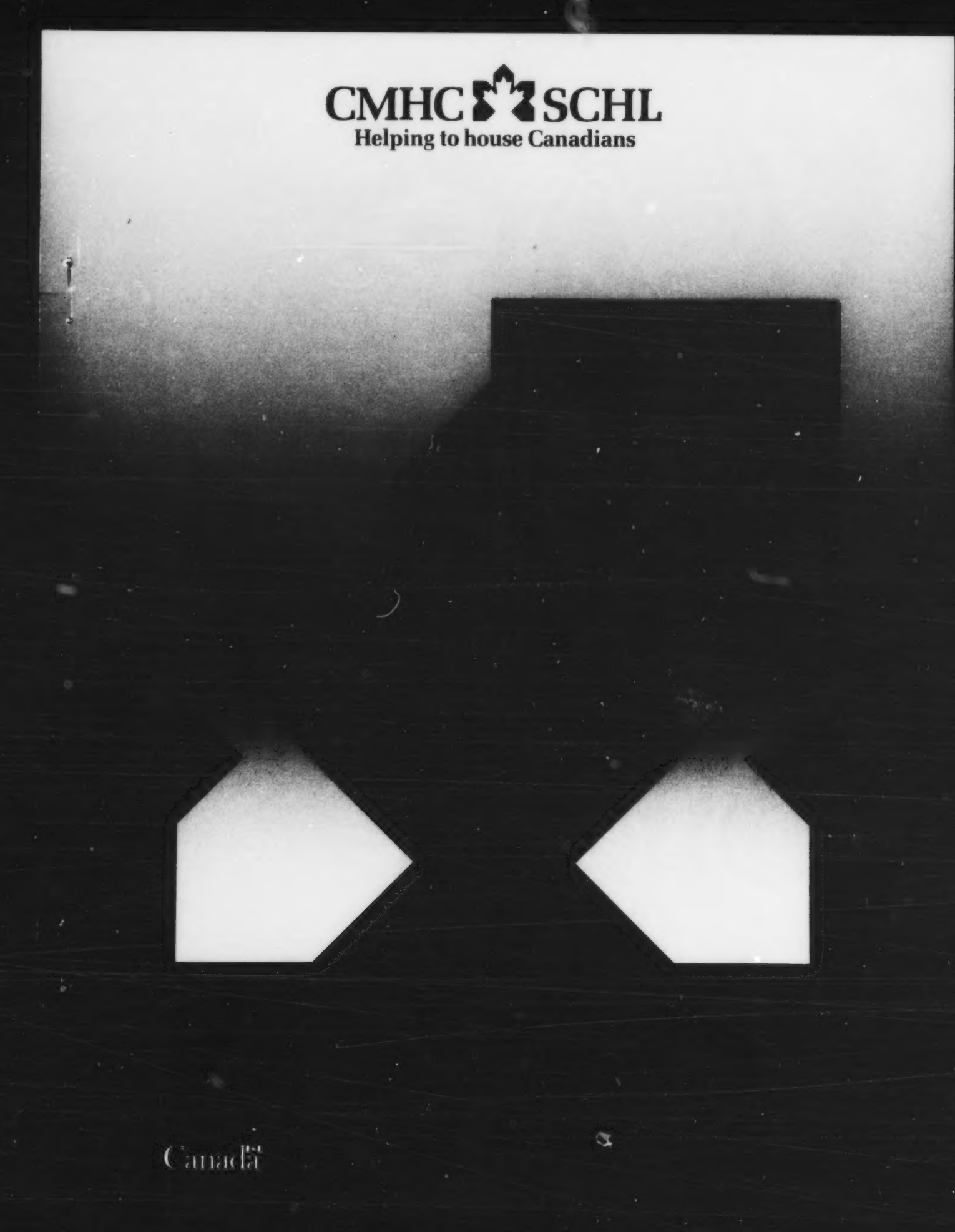
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LONG TERM PERFORMANCE OF CONTOUR TRENCH SYSTEMS FOR SUBSURFACE DISPOSAL OF SEPTIC TANK EFFLUENT FROM MULTIPLE DWELLINGS

By G.M. Charles, D.H. Waller and J.D. Mooers
CWRS Internal Report 90-12
November 1990

CMHC Project Manager: Al Houston

This project was carried out with the assistance of a grant from Canada Mortgage and Housing Corporation under the terms of the External Research Program (CMHC CR File 6585/W29). The views expressed are those of the authors and do not represent the official views of the Corporation.

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ABSTRACT

An experimental contour trench system for subsurface disposal of septic tank effluent from a group of dwellings was installed at Port Maitland in southwestern Nova Scotia in 1982, in order to address the problem of failing individual septic systems in that community. A contour trench disposal field is a relatively narrow and shallow disposal bed constructed in a trench of constant depth, dug along a contour of the ground surface, such that the trench bottom and the lip of the trench wall are absolutely horizontal throughout the entire length. The Port Mainland system was originally monitored between 1982 to 1984, the site was revisited and monitored from May of 1989 to June of 1990, by the Centre for Water Resources Studies at the Technical University of Nova Scotia in a study conducted for Canada Mortgage and Housing Corporation, to assess the long-term hydraulic and treatment performance of the system. Piezometer nests remaining from the original study were re-used. Samples were collected, and groundwater depths observed, on seven occasions. Analyses were conducted for bacteriological and chemical parameters.

The system is installed in a glacial till deposit of low permeability and seasonally high groundwater. Findings show that chemical concentrations of contaminants were reduced to background levels within 9m of the contour trench. There was no apparent increase in the transport distance between 1984 and 1990. Comparisons of chloride attenuation vs. other parameters indicated that soil adsorption and/or chemical change, in addition to dilution, is responsible for improved water quality.

Bacterial removal varied with groundwater levels, but the combined effects of removal through vertical transport in the unsaturated soil and during lateral transport in saturated soil of low permeability substantially reduced or eliminated total and fecal coliforms.

Results confirm the need to locate upstream interceptor trenches to avoid contaminant backflow. The successful operation of this system in an area of high (1000-1400 mm) rainfall supports its use in areas of lower precipitation.

"Rendement à long terme des systèmes de fossés de niveau pour l'évacuation souterraine des effluents de fosse septique de logements collectifs"

ABRÉGÉ

Un système expérimental de fossés de niveau, pour l'évacuation souterraine des effluents de fosse septique d'un groupe d'habitation, a été installé en 1982 à Port Maitland, dans le sud-ouest de la Nouvelle-Écosse, en réponse aux problèmes de défaillance des systèmes septiques individuels dans cette localité. Un champ d'épuration par fossé de niveau est un lit d'épandage relativement étroit et peu profond constitué d'un fossé de profondeur constante, creusé le long du contour de la surface du sol, de manière à ce que le fond du fossé et le bord du mur du fossé soient absolument horizontaux sur toute sa longueur. Le système de Port Maitland est resté en observation, au départ, entre 1982 et 1984, et le site fut revisité et contrôlé de mai 1989 à juin 1990 par le Centre for Water Resources Studies de la Technical University of Nova Scotia dans le cadre d'une étude réalisée pour la Société canadienne d'hypothèques et de logements pour évaluer la performance à long terme du système, tant sur le plan hydraulique que du point de vue de l'épuration. Les nids de piézométriques qui restaient de l'étude originale furent réutilisés. Des échantillons furent recueillis, et la profondeur des nappes souterraines observées à sept occasions. On a également effectué des analyses relatives aux paramètres bactériologiques et chimiques.

Le système est installé dans une moraine de faible perméabilité et où la nappe phréatique est plus ou moins élevée, selon la saison. Les observations font ressortir que les concentrations chimiques de contaminants sont réduites à un niveau naturel dans un rayon de 9m du fossé de niveau. On n'a constaté aucune augmentation apparente de la distance de transport entre 1984 et 1990. Des comparaisons portant sur l'atténuation de chlorure par rapport à d'autres paramètres ont montré que l'absorption du sol et/ou le changement chimique, en plus de la dilution, améliorent la qualité de l'eau.

L'élimination bactérienne variait selon les niveaux de la nappe phréatique, mais les effets combinés de l'évacuation par transport vertical dans le sol non saturé, et au cours du transport latéral dans des sols saturés de faible perméabilité, réduisaient substantiellement ou éliminaient les coliformes généraux et fécaux.

Les résultats confirment qu'il est nécessaire de placer des fossés-intercepteurs en amont, afin d'éviter un refoulement de contaminants. Le fonctionnement satisfaisant de ce système dans une région pluvieuse (1 000 - 1 400 mm), justifie son utilisation dans des régions où les précipitations sont faibles.

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ACKNOWLEDGEMENT

The Centre for Water Resources Studies wishes to thank Canada Mortgage and Housing Corporation for support in the funding of this project. The interest and assistance of A. Houston , project administrator, is gratefully acknowledged.

DISCLAIMER

The methodologies, the interpretations and the recommendations are those of the consultants and do not necessarily reflect the view of Canada Mortgage and Housing Corporation, which assisted in the study and its publication. The results of the study are published for information purposes and the reader is cautioned that the scientific data generated are derived from a study of one specific operating contour trench system in Port Maitland, Nova Scotia.

Extrapolation of this data to other contour trench systems across Canada may be feasible, provided that the vagaries of climates and the behaviour of various drainage systems and soils in those local areas are understood.

INTRODUCTION

The Centre for Water Resources studies (CWRS) at the Technical University of Nova Scotia (TUNS) has committed itself to a long-term program of research directed to improvement of the design and operation of on-site sewage disposal systems. The program has received substantial support from departments of the Nova Scotia government.

The program has focused on contour trench systems, developed by the Nova Scotia Department of Health and Fitness, which form the basis of current regulations in the province. The concept was evaluated, with the support of Canada Mortgage and Housing Corporation (CMHC), in a two-year study of several multi-dwelling systems at Port Maitland, Nova Scotia (1). The results supported the design philosophy that underlies the provincial regulations.

Although the original Port Maitland study satisfied short-term concerns about the performance of these systems, the long term, steady state hydraulics and water quality of these systems was not fully assessed. Understanding the long term migration of effluent from these systems is important in understanding their potential impact on regional groundwater systems.

The sampling network established for the initial Port Maitland study provided an opportunity to revisit the site to examine the long term performance of one of the systems that was monitored in the original study. This report is the result of a study conducted in the period May 1989 to June, 1990, with the support of the External Research Program of CMHC.

The findings of this report are intended to provide legislators, municipal authorities and consultants, who are faced with the problems of developing a cost-effective long term domestic wastewater disposal system for small communities and institutions, with a sound alternative design concept.

OBJECTIVES

The purpose of this study was to attempt to confirm that large scale contour trench systems can offer an effective and efficient method for long term treatment of wastewater disposal for small community systems. Specifically, the objectives of the project were to:

- Examine and compare key chemical and bacterial components as well as groundwater flow characteristics within a given location, with similar data collected during the infancy of the system under a separate CMHC contract.

- Determine the long term effectiveness of a large scale septic system and confirm the applicability of these designs in Nova Scotia and other regions across Canada.

SITE DESCRIPTION

Port Maitland is a small community located approximately 20 km north of Yarmouth, Nova Scotia (Figure 1). The specific region of this study is part of a larger Wastewater Management District comprised of several contour fields fed either by gravity flow or siphon tanks. The community is largely residential with a population of about 350 people. There are no significant industrial or commercial contributors to this system.

The complete system installed at Port Maitland in 1982 included two contour trench systems. One of these, designated system B in the original study, was selected as the basis for the current research. The monitored contour field includes two wastewater distribution trenches separated by approximately three meters (Figures 2 and 3). Figure 2 shows the plan view of the site. Fed by a siphon chamber, the two trenches operate in an alternating fashion over six month intervals. The siphon chamber discharges septic wastewater an average of four times each day. Two meters up-slope from the two septic distribution trenches is an interceptor trench (Figures 2 and 3) designed to collect overland flow and lower the groundwater table. The annual precipitation for this region varies between 1000 and 1400 mm, much higher than most other regions of Canada.

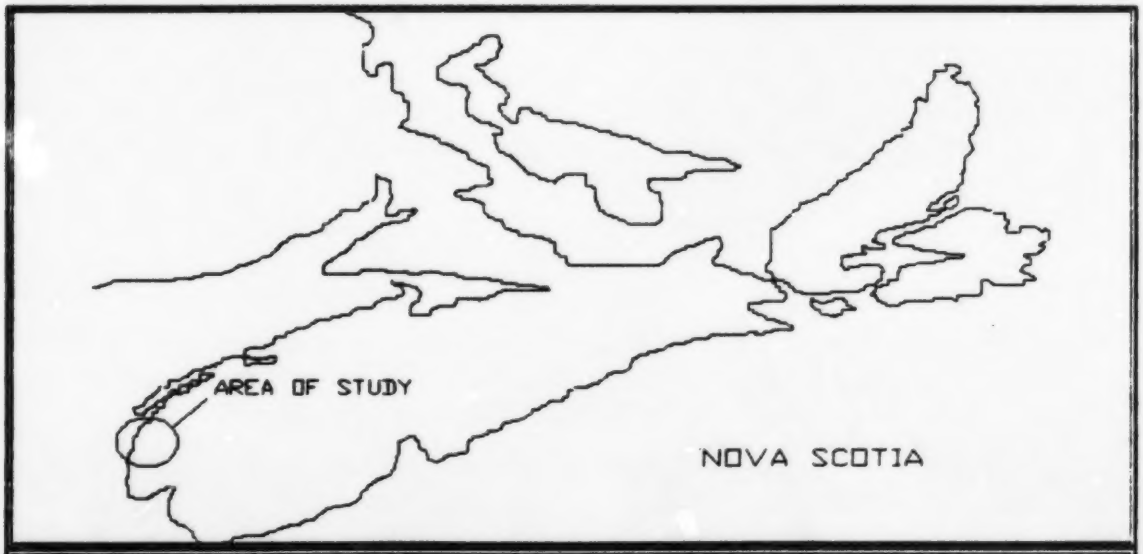


Figure 1. Location of Study

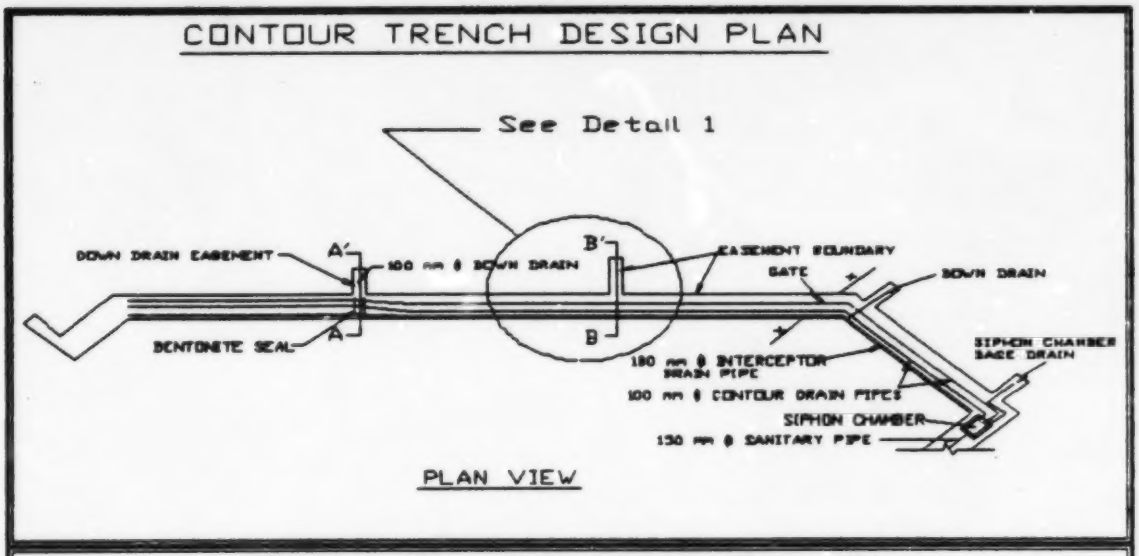


Figure 2. Plan of Study Area (From (1))

Monitoring Design

The original monitoring network was comprised of a series of single and multilevel piezometers installed throughout a small region of the bed. Initially, eleven single level and eight multilevel piezometers were installed. Some of the single level piezometers were not

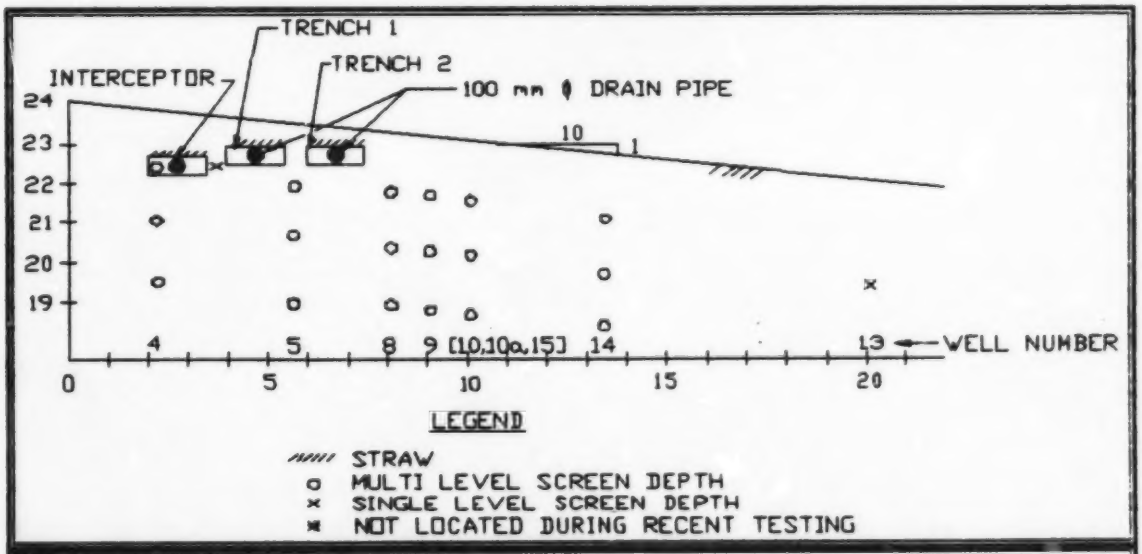


Figure 3. Section Through B'-B'

found, presumably destroyed by farming activities. The details of each type of piezometer are shown in Figures 5 and 6.

The multilevel piezometers were oriented principally in a downslope direction starting at the interceptor trench (see Figure 4). The relative depths below grade of the upper, middle and lower screens in each piezometer are 1.5m, 3.0m and 4.5 meters respectively. Two multilevel piezometers are offset by two meters to the left and right of well number 10, approximately three meters downslope from the lowermost distribution trench.

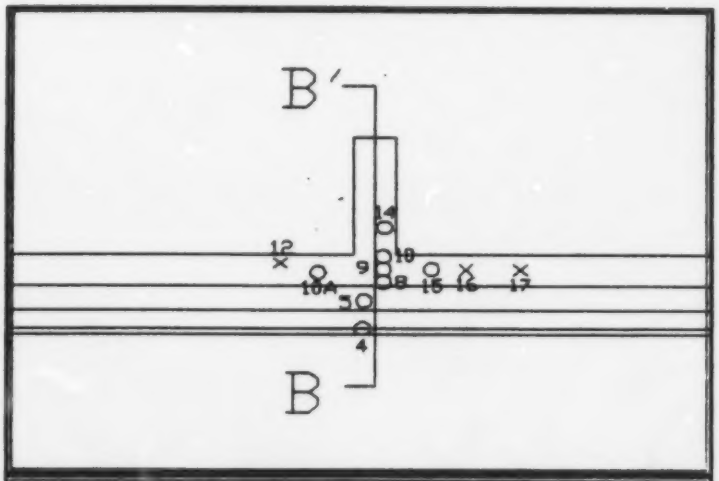


Figure 4. Detail of Piezometer Nest

SITE GEOLOGY

The regional geology of Port Maitland is documented in the original study (1) as follows:

> The Port Maitland area is underlain by Meguma Group slate and quartzite bedrock. The bedrock lies at depth in this community, covered by a drumlin till deposit. The elongated topographical high running parallel to the main community road consists of a complex of till types and overlying soils. System B was constructed over a moderate to highly compacted silty till, yellowish grey (Geological Survey of Canada rock color chart designation 5 YR 7/2), friable and containing varying amounts of pebbles, cobbles and small boulders. The silty till penetrated to a depth of 2.5 m where it is underlain by a compact sandy, silty till, dusky yellow (5 YR 6/4) containing broken subrounded cobbles and pebbles with minor amounts of quartzite pebbles. Several weathered zones located between 2.5 and 4.5 meter depth were identified by reddish brown mottled till of higher permeability.

The soils derived from the underlying silty till consist of a moderate brown (5 YR 3/4) moderately compact silt with a total depth of approximately 0.6m. A thin 5 to 8 cm section of sand was identified below the 10 cm depth root zone. This section was friable and contained numerous small pebbles. The lower section of the soil zone below the sand consisted of a weathered and mottled compact silt. Although the soil-till interface was very compact, the material was gritty and friable. It is probable that the upper soil horizon has a permeability several orders of magnitude greater than the underlying till, however, percolation test results indicate that System B is constructed in low permeability compact soils.

Subsequent to the initial project it was found that the entire field was in fact almost entirely constructed on soils of very low permeability, in the order of 4.5x10-6 (5) m/s.

METHODOLOGY

In order to fully evaluate the annual performance of the Port Maitland Contour System, five sets of data were collected from the site between May 1989 and January 1990. As the piezometers were four years old, two days were allocated to the rejuvenation of the twenty-one piezometers using successive withdrawal and natural recharging to clean out the wells. Following the reactivation period, each collection event required only one day. Each of the piezometers were first monitored to assess the hydraulic head at various points throughout the field and also establish the location of the groundwater surface. Head elevation data was collected using a portable electric sensor with two wire leads which

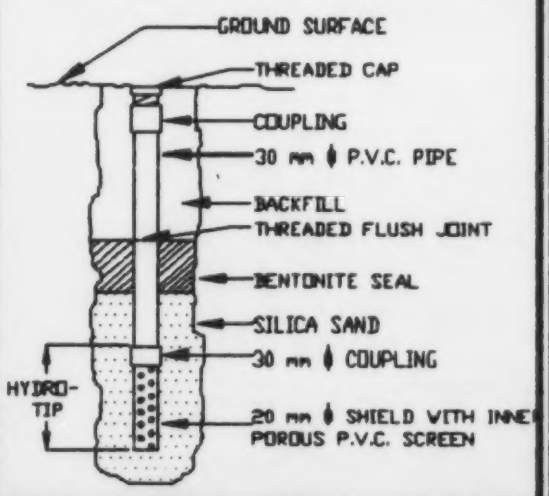


Figure 5. Single Level Piezometer

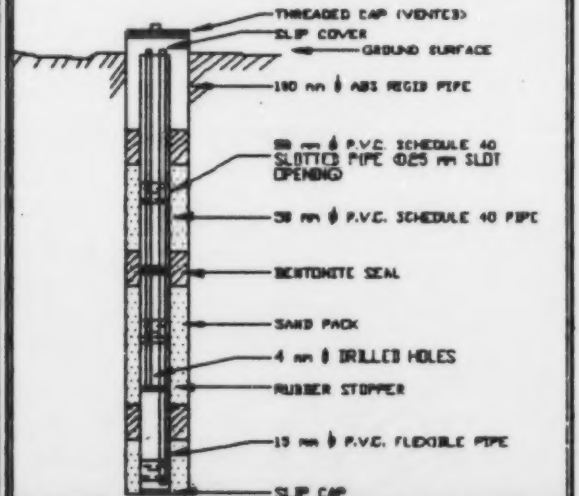

THREADED CAP (VENTED)
SLIP COVER
GROUND SURFACE
100 mm ϕ ABS RIGID PIPE
50 mm ϕ P.V.C. SCHEDULE 40 SLOTTED PIPE Ø25 mm SLOT OPENING
38 mm ϕ P.V.C. SCHEDULE 40 PIPE
BENTONITE SEAL
SAND PACK
4 mm ϕ DRILLED HOLES
RUBBER STOPPER
13 mm ϕ P.V.C. FLEXIBLE PIPE
SLIP CAP

Figure 6. Multi-level Piezometer

were lowered into each piezometer. The piezometers were then completely drained with the aid of a 120 volt peristaltic pump and portable generator. Each piezometer was pumped and permitted to recharge at least three times before the final sample was collected. Sampling started at the most distant wells and moved progressively closer to the septic distribution trenches. Between each collected sample, 500 ml of distilled water was passed through the pump tubing. Samples were shipped to Halifax, Nova Scotia and analyzed at the Victoria General Hospital's Environmental Chemistry Laboratory. Total coliforms as well as fecal coliforms were analyzed at the nearby Yarmouth Regional Hospital, in order to minimize bacterial growth/die-off. Table 1 lists the analyses conducted on each sample. Analyses were conducted according to Standard Methods (4).

Biochemical and Chemical Oxygen Demand (BOD,COD) were evaluated on the first sample set, in the hope that if a relationship between BOD,COD with TOC was established, the number of analyses could be reduced.

The data were plotted as a function of depth and distance relative to the septic disposal trench and compared with the same data obtained in 1983-84. Similar contouring of the hydraulic head was done to examine any long term changes in hydraulic characteristics of the soil due to septic leachate. All contouring was performed on an IBM PC using a commercially available interpolation software package designed for this task (Surfer, Golden Software).

Total Organic Carbon
Chlorides
Ammonia Nitrogen
Total Kjeldal Nitrogen (TKN)
Nitrates & Nitrites (NOx)
pH
Total & Fecal Coliforms
BOD

Table 1. Parameters Assessed in Study

OBSERVATIONS

Field Hydraulics

The system operates under varying climactic conditions throughout the year, which influence the water table position relative to the distribution trenches. As noted in the original study back-flow conditions do occur between the interceptor trench and the distribution trenches when the groundwater is in contact with each. Typically, the system exhibited back-flow between late November through January and late April through July. With the exception of the transient, localized flow pattern near the trenches, the system operates mostly in a lateral direction, with a gradient of approximately 10%. A typical flow net is illustrated in Figure 10 showing the direction of flow. Figure 7 shows the variation in

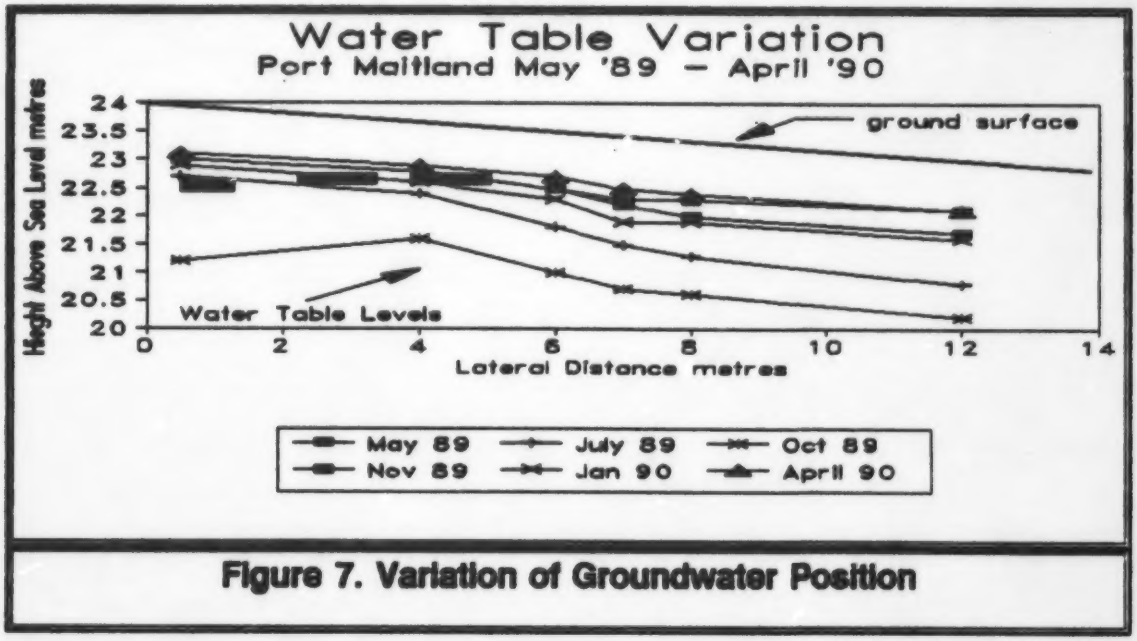


Figure 7. Variation of Groundwater Position

the water table position throughout this one year study period. Groundwater mounding is clearly observed during drier months such as July and October. Comparison of 1989-90 data to 1984 data shows little change in the long term field hydraulics.

Chemistry

Chlorides

After approximately one year of operation, the chloride plume appeared to become stable in form (1). Figures 8 and 9 compare the chloride plume profile of May 1984 with that of May 1989. Although slight differences do exist, the plume profile is relatively unchanged and is more influenced by annual water table fluctuations as illustrated in Appendix D. Like most of the chemical parameters involved in this study, the high annual rainfall appeared to contribute substantially to the dilution of chlorides as they moved through the groundwater. Table 2 summarizes the approximate region of influence based upon 1989 and 1990 data. The maximum lateral migration of chloride (based on an assumed background level of 50 mg/l) extended approximately 9 meters from the distribution trench, and to a maximum depth of about 4 meters.

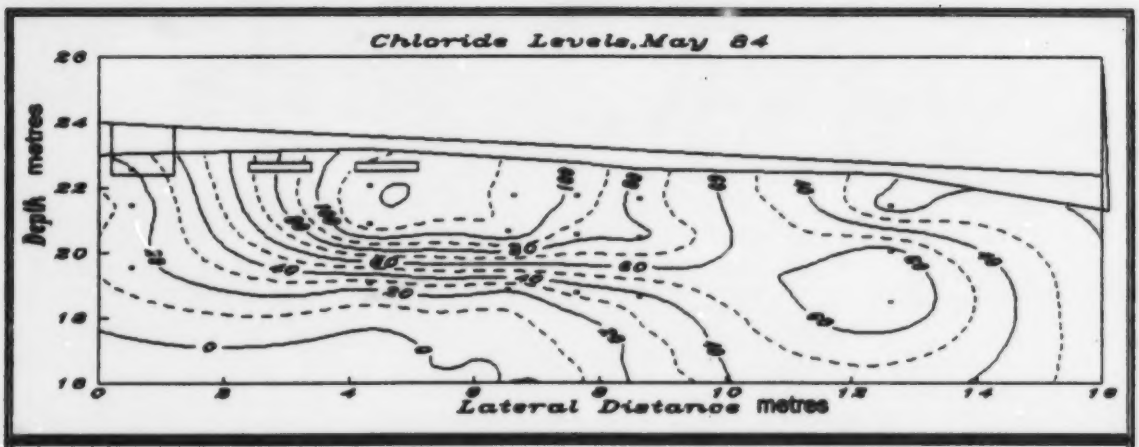


Figure 8. May 1984 Chloride Plume Profile

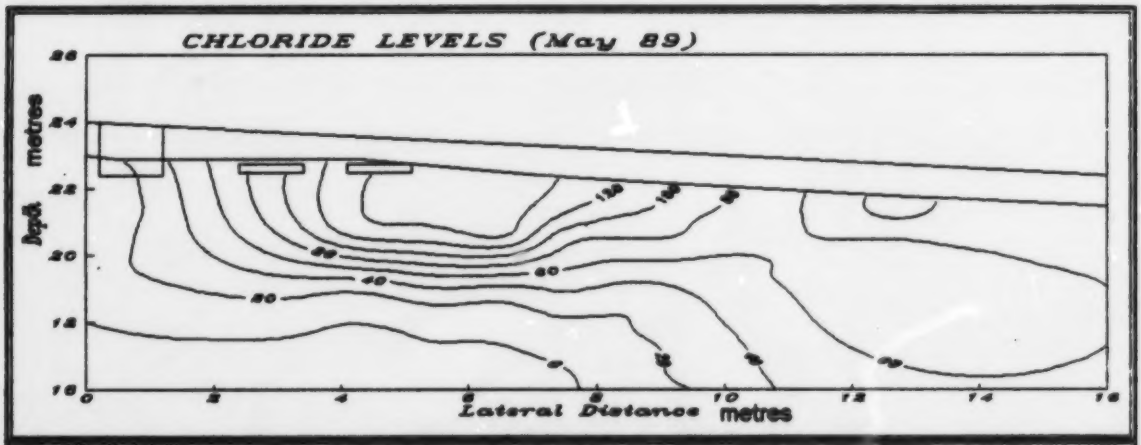


Figure 9. May 1989 Chloride Plume Profile

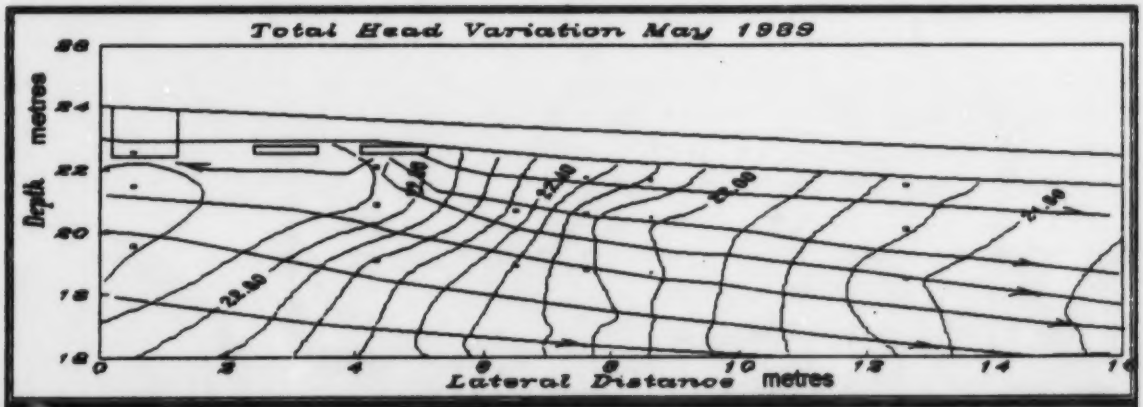


Figure 10. Typical Flow Net of Site

Parameter	Concentration [mg/l]	Lateral Transport [m]	Vertical Transport [m]
Chloride	50	9	4
TOC	70	4	3
Ammonia	0	9	3
Nitrate	10	9	4
C.O.D.	50	4	3
B.O.D..	0	9	3

Table 2. Summary of Plume Features

T.O.C., C.O.D., B.O.D.

On the first sample set, May 1989, each of the wells were tested for Total Organic Carbon (TOC), Chemical Oxygen Demand (COD), and Biological Oxygen Demand (BOD). From this data a correlation was developed to assess the region of BOD and COD influence based upon TOC results. Table 3 displays the results of the comparison, which indicates the concentrations of both BOD and COD are closely correlated with TOC concentrations. These results supported a decision to eliminate BOD and COD analyses for subsequent samples.

Based upon a 15 mg/l isopleth, the TOC extends outward and downward a distance of 4 meters and 3 meters respectively. The COD values (for a 50 mg/l isopleth) extend out approximately the same distance as the TOC. BOD is also attenuated to relatively low levels (below 5 mg/l) over a similar distance.

	#Samples	Relation	R2
TOC vs BOD	14	[BOD] = 0.99* [TOC]	0.98
TOC vs COD	17	[COD] = 2.9* [TOC]	0.91

Table 3. Summary of Plume Features, Various Parameters

Figures 11 through 16 compare these three chemical parameters between 1984 and 1989. Like the chloride plume, these comparisons show little change over this five year period. A complete summary of the TOC sampling may be found in Appendix E.

Total and Fecal Coliforms

Limited bacteriological analyses were conducted in the Porter Dillon study (1). Total coliform and fecal coliform counts were measured in this study to determine the effectiveness of the system in reducing bacteria counts.

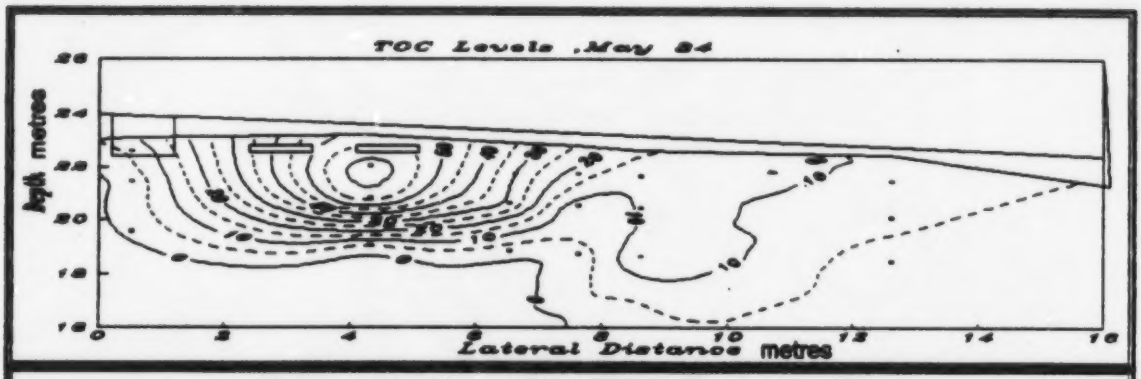


Figure 11. May 1984 TOC Plume Profile

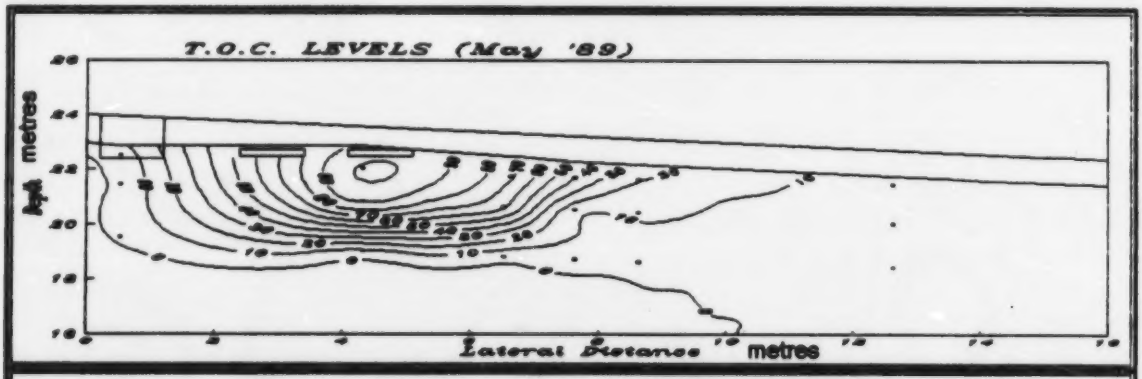


Figure 12. May 1989 TOC Plume Profile

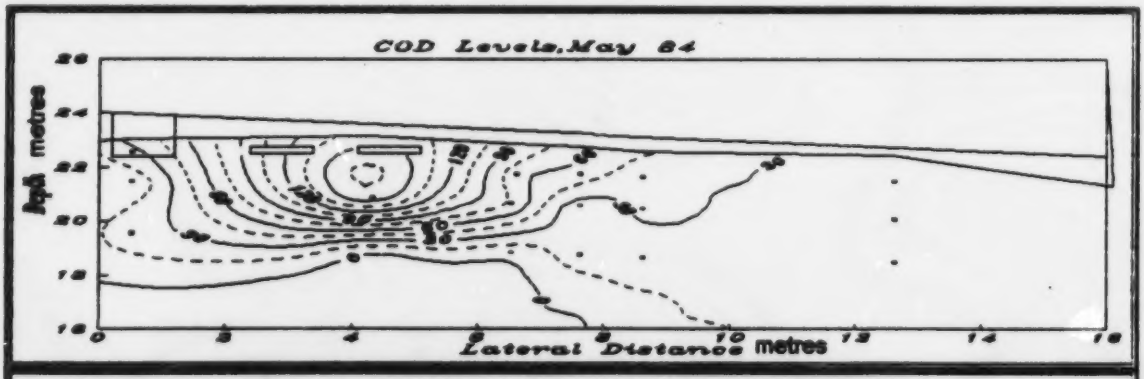


Figure 13. May 1984 COD Plume Profile

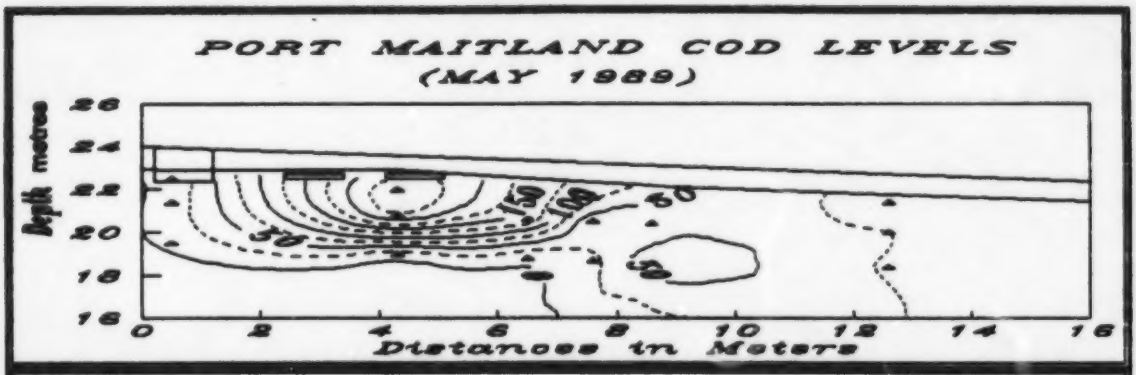


Figure 14. May 1989 COD Plume Profile

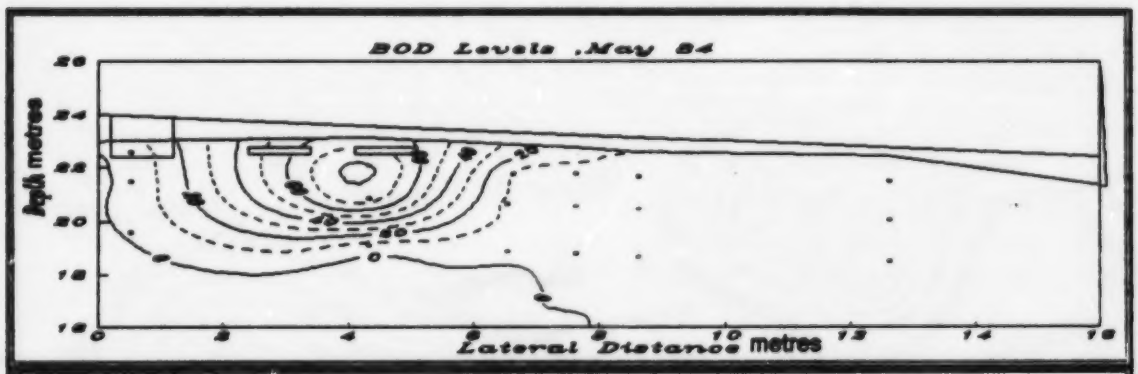


Figure 15. May 1984 BOD Plume Profile

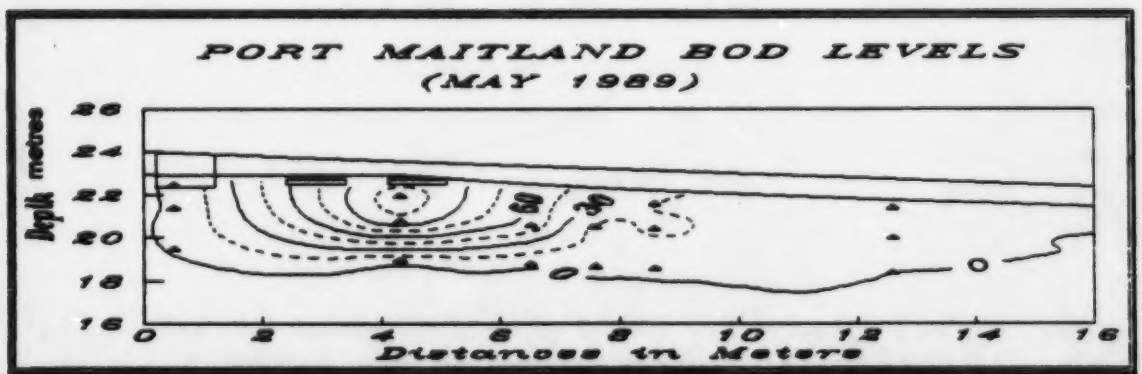


Figure 16. May 1989 BOD Plume Profile

Cold weather sampling was carried out in November 1989 and January 1990. During both periods, high total coliforms levels were found at most piezometers. As the groundwater table conditions were similar to the May and July sampling, the finding of high total coliforms at all wells (>1000 /100 ml) was somewhat inconsistent. It was later felt that cross contamination between successive well sampling, particularly during the November data set, may have resulted from in-line icing of the pump tubing, making these winter bacterial results unreliable.

Table 4 summarizes total coliform counts immediately downslope of the contour trench (piezometer 8) , at the furthest downslope piezometer sampled (piezometer 14), and the range of values of all piezometers. The table also includes groundwater levels relative to the bottom of the contour trench. Comparison of October values at piezometer 8 with those for other months suggests that vertical transport through 1 meter unsaturated soil virtually eliminated total coliforms. Effects of lateral transport in the saturated till are indicated by consideration of results for piezometer 14, which are at least an order of magnitude lower than those for upstream piezometers.

As in the previous study, total coliforms were found up-slope from the distribution trench in piezometer 4, indicating the problem of back-flow continues to occur, particularly during periods of high groundwater table elevation. Wastewater back-flow has resulted from the close placement of the interceptor trench in relation to the distribution trenches, allowing short circuiting of the effluent in an apparently up-slope direction. The field appears not to have this problem if the two trenches are hydraulically isolated from potential saturated flow(as in the case of the drier summer months).

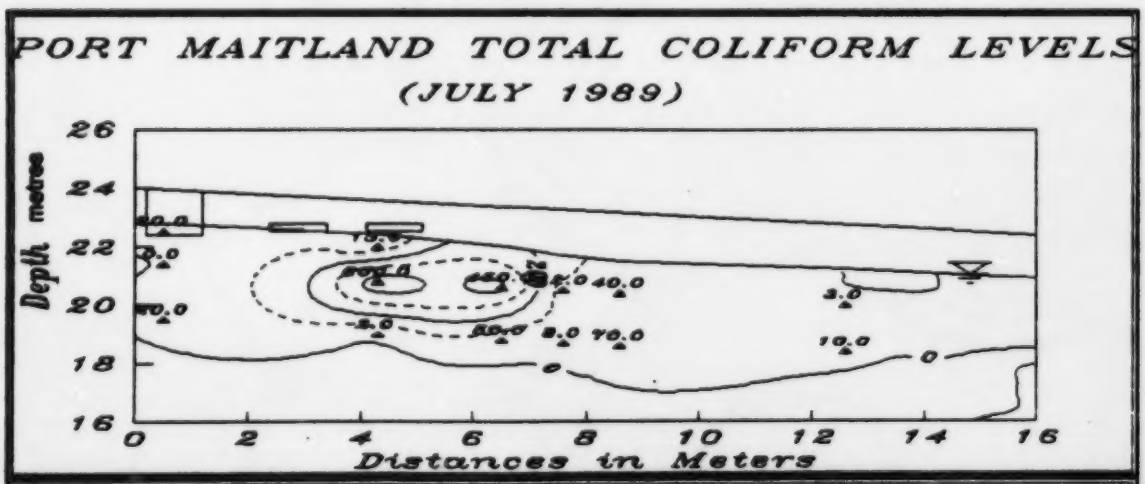


Figure 17. Total Coliforms Plume July 1989

Sampling Date	Groundwater level above bed bottom[1] (m)	Bacterial Counts Total Coliforms per 100ml		
		well #8	All Wells	Well # 14
May 1988	+0.3	10 - 1100	0 - 1100	20 - 180
July 1989	+0.05	50 - 450	0 - 500	3 - 10
October 1989	-0.66	0	0 - 20	0
November 1989[2]	+0.27	52 - >1000	0 - >1000	0 ->1000
January 1990[2]	+0.13	2 - 7100	0 - 7100	0 - 30
April 1990	+0.39	38 - 700	0 - >1000	0 - 27
June 1990	+0.9	18 - >1000	0 - >1000	1 - 30

Table 4. Relationship of Bacterial Counts to Groundwater Level and Location.

[1] Based on mean readings from piezometers 4 and 8, level 1
[2] Bacterial results suspect

Nitrogen

Nitrogen in the vicinity of the contour trench appears mainly in the form of ammonia. Only in the area adjacent to the distribution trenches does Total Kjeldhal Nitrogen (TKN) vary from ammonia. Using the 0 mg/l isopleth, ammonia nitrogen influences an area that extends laterally and vertically from the distribution trench to a distance of 9 meters and 3 meters respectively. Nitrates appear to increase slightly in concentration with increasing depth, although the levels do not exceed 5 mg/l. Figures 18 and 19 provide a comparison

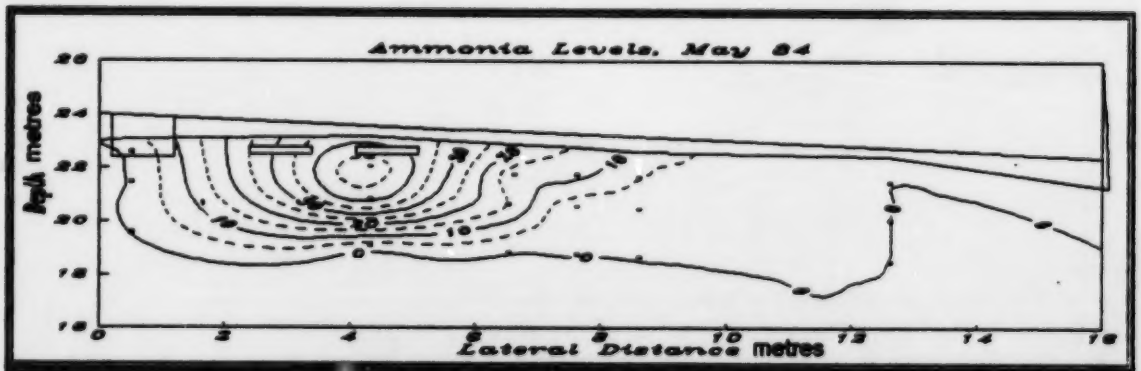


Figure 18. May 1984 Ammonia Plume Profile

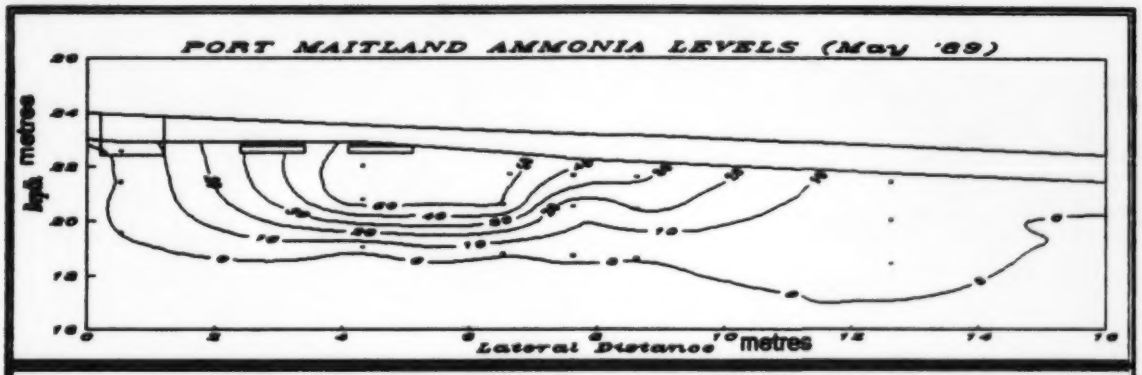


Figure 19. May 1989 Ammonia Plume Profile

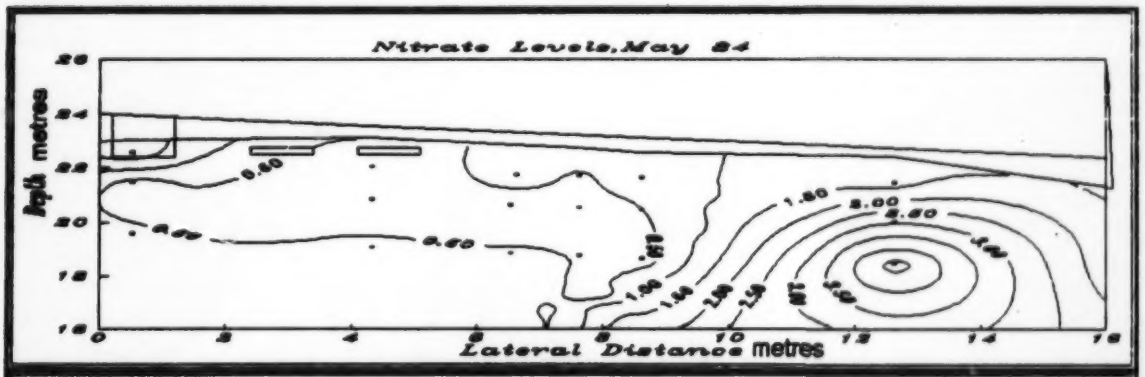


Figure 20. May 1984 Nitrate Plume Profile

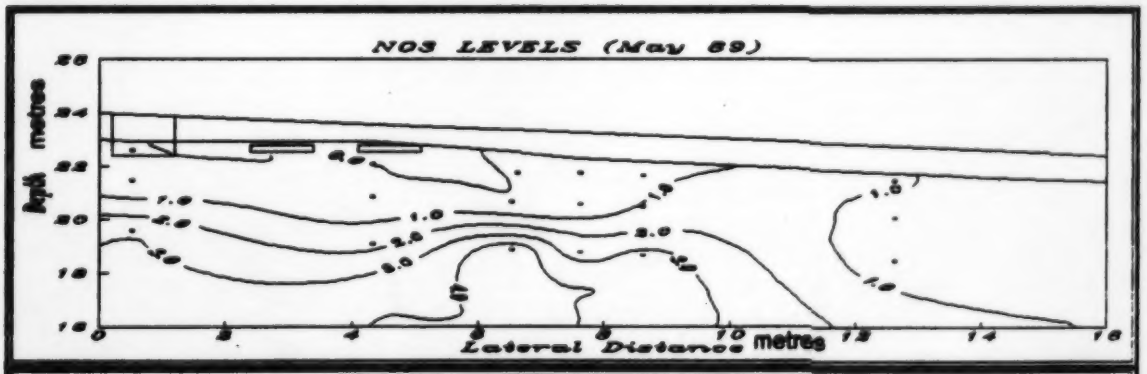


Figure 21. May 1989 Nitrate Plume Profile

between ammonia profiles of May 1984 with those of May 1990. It can be seen that very little difference exists although annual variations do occur, as seen in Appendix B,

Lateral Distribution of Effluent Plume

The site was also monitored parallel to the distribution trench, approximately five meters away and two meters below the ground surface. This lateral survey included single level piezometers 11,12,16,17 as well as level 2 of the multilevel piezometers 10A, 10 and 15. In almost all the wells sampled, the values of the various parameters were similar. A summary of the well water quality is presented in Figure 22. The one parameter not included in this graph was the distribution of the total coliforms. For both the April and June 1990 data sets, these wells all showed levels of total coliforms greater than 1000 mpn per 100 ml.

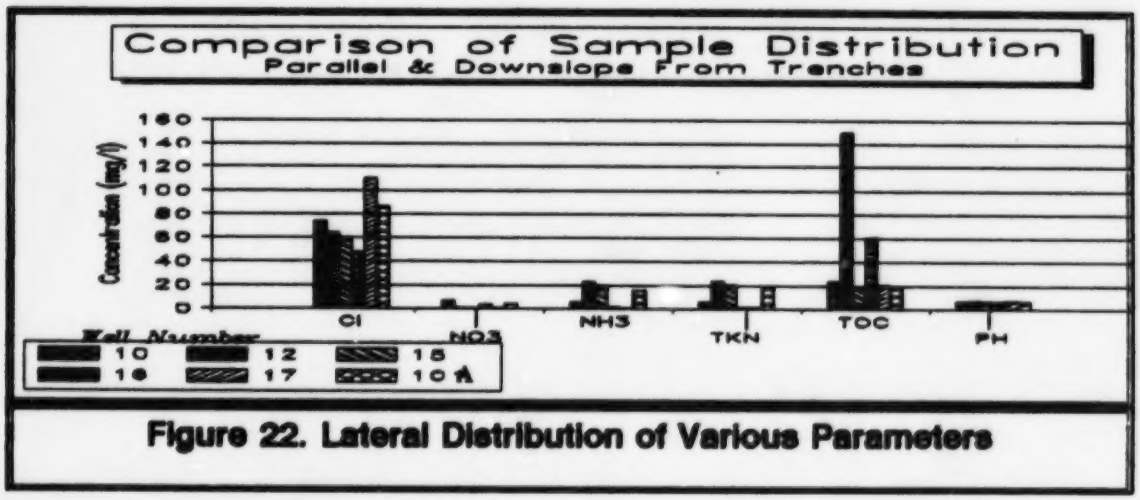


Figure 22. Lateral Distribution of Various Parameters

Discussion

The Port Maitland site appears to operate under a relatively consistent pattern with respect to the chemical species analyzed. Comparing data collected in May of 1984 to that of May 1989 and June of 1990, little variation can be seen in the attenuation profiles. The data tends to suggest that the development and aerial extent of the wastewater effluent plume is strongly coupled to the changes in seasonal rain and groundwater position. The shape of the plume is best displayed by the chloride concentration gradient shown in Figures 8 and 9. Chloride concentrations reach approximately 120 mg/l in the area of the distribution beds, while 9 meters downslope from the trench, concentrations are reduced to approximately 50 mg/l, a ratio of 2.5:1. The other analyzed parameters show a similar distribution, however, their concentration reduction is greater over the same 15 meters ; TOC is reduced by 6:1; COD by 5:1; BOD, fecal coliforms, and ammonia are completely removed. Nitrate increases from 0 to 3 mg/l, likely a result of the oxidation of ammonia. Although this is a mature system, the effects of adsorption and dilution continue to remove wastewater contaminants at a rate which have stabilized the effluent plume.

Bacterial transport appears to respond to climatic variables. Higher precipitation results in higher groundwater tables and more rapid groundwater movement. High groundwater levels reduce or eliminate the distance of vertical transport through unsaturated soil below the distribution trench. Higher flow rates reduce soil contact time in the saturated zone. Both effects appear to increase downslope bacterial counts. Nevertheless, even in wet periods total and fecal coliform counts were substantially reduced, and in dry periods eliminated, within 9 meters of the trench.

The overall hydraulics of this site can be deduced from the chloride plume data as well as the flow net information. The principal flow is in the lateral direction with a substantial transport region in the upper meter of the groundwater table. Although not addressed in this study, there is likely a nominal flow through the unsaturated soil horizon. As most of the recharge originates from precipitation, the height of the water table relative to both trench bottoms was highly variable. During the early spring and late fall the trenches came into contact with the groundwater table. In this condition, a short circuiting or back-flow towards the interceptor trench arose causing poor treatment, as noted by an elevated coliform count and odour at the interceptor outflow. This was a prototype design problem which has since been addressed and modified in the current Nova Scotia contour design codes, taking into account the cumulative effects of groundwater fluctuation and recharge mounding in the vicinity of the distribution trenches. Despite this intermittent back-flow problem, the majority of treatment occurs in a downslope direction, following the natural gradient of the land.

According to current N.S. Department of Health and Fitness guidelines, this field would have been designated a "C2" class field in which the distribution trench would be positioned at the ground surface and covered by a select sand, extending downslope at least four meters with thickness of 300mm. A typical C2 design (see figure 23), derived from the original study, takes advantage of the relatively high conductivity of the "A" soil horizon and provides a greater separation distance between the trench bottom and the surface of the groundwater table resulting in improved performance and less threat of contaminant travel. Given the strong lateral flow component of this site and the relatively high water velocity of the upper soil horizons, it is believed that an overall improvement would be seen if a C2 design had been initially implemented. The improvements to contour trench disposal field design resulting from this and the previous study (1) provide a means of treating domestic wastewater in regions hampered by fine, sandy silts with moderate to low permeability(~ 10E-6 m/s), exposed to prolonged periods of near surface groundwater and high annual rainfall (1000-1200 mm).

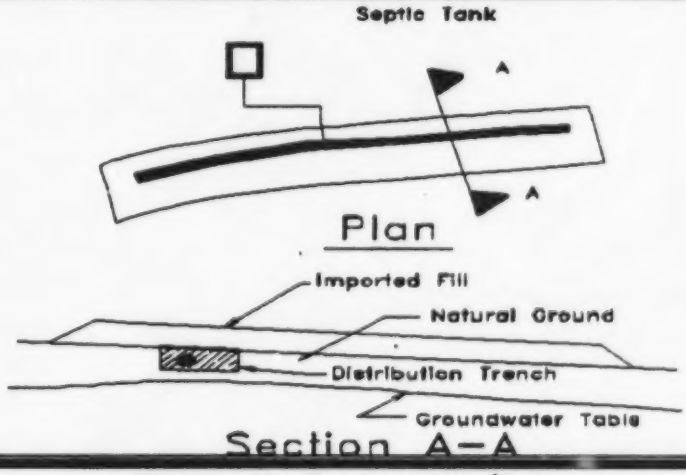


Figure 23. Typical C2 Field

Conclusions

The contour septic field design has proven to be an acceptable method of treating the wastewater discharge of small communities forced to operate septic fields in soils with low permeability, and high fines content. Specifically, this study has found:

- the Port Maitland system continues to meet its design objectives 8 years after its installation.
- location of the groundwater interceptor trench should be approximately 3 meters up-slope of the disposal beds with a minimum depth of 0.3 and 0.6 meters respectively.
- changes in the Nova Scotia on-site sewage disposal regulations, subsequent to the Port Maitland installation, are expected to further improve the performance of contour trench systems.
- despite seasonal variations in bacterial removal, associated with high groundwater levels, total and fecal coliforms were eliminated or substantially reduced within 9 meters of the contour trench.
- comparison of chloride with other parameters indicates that soil adsorption and/or chemical change results in attenuation to background levels within 9m in the low permeability Port Maitland soils.
- comparison of chemical distributions in May of 1984 and May of 1990 indicates no apparent difference in chemical transport distance over this period.
- it is expected that transport of potential contaminants would be less if exposed to lower rainfalls such as occur in other regions of Canada.

References

(1) Porter Dillion Ltd, 1985, "Monitoring Results of the Port Maitland Contour Trench B Septic Waste Disposal System", Prepared for the CMHC Research Sector

(2) Freeze et al, 1979, "Groundwater", Prentice Hall Inc., Englewood Cliffs, N.J.

(3) Nova Scotia Department of Health and Fitness, Feb. 1988, "On-Site Sewage Disposal Systems Technical Guidelines"

(4) APHA, AWWA, WPCF, 1985, "Standard Methods For The Examination of Waste and Wastewater', APHA Washington D.C.

(5) Charles,G.M., Waller,D.H., "Field Evaluation of In-Situ Permeability Tests for Site Characterization and Septic Field Design", Centre for Water Resources Studies, Contribution No. 90-5, Technical University of Nova Scotia.

Appendix A

DATE	WELL	LEVEL	N-TKN	N-NO3	N-NH3	Cl	BOD	TOC	COD	pH	Coliforms		Head
											Fecal	Total	Meters
			mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l		/100 ml	/100 ml	A.S.L.
9-May-89	4	1	9	0.1	0.1	12	2	3	6.6	6.3	-0-	30	22.906
9-May-89	4	2	5.5	0.15	0.06	10	2	1	11	6	-0-	10	23.116
9-May-89	4	3	0.5	3	0.05	18	2	1.4	7.2	6.8	-0-	0	23.066
9-May-89	5	1	58	0.05	58	140	114	104	246	7	-0-	20	22.904
9-May-89	5	2	60	0.05	58	140	106	96	235	6.9	-0-	260	22.894
9-May-89	5	3	1.8	1.7	0.61	19	2	2.6	7.2	6.5	-0-	20	22.574
9-May-89	8	1	53	0.05	53	160	53.7	73	151	6.8	-0-	1100	22.499
9-May-89	8	2	52	0.05	52	150	56.2	64	146	6.9	-0-	500	22.479
9-May-89	8	3	0.5	5	0.05	23	2	1.8	5	6.9	-0-	10	22.289
9-May-89	9	1	36	0.75	36	130	28.7	40	78	6.5	-0-	300	22.316
9-May-89	9	2	9	0.21	9	80	9.3	9	26	6.9	-0-	70	22.116
9-May-89	9	3	2.7	2.4	2.2	36	4.7	4.8	15	6.8	-0-	60	22.116
9-May-89	10	1	32	0.89	32	110	14.3	20	56	6.6	-0-	150	22.197
9-May-89	10	2	21	1.1	21	78	10.8	13	44	6.7	-0-	800	22.007
9-May-89	10	3	2.5	3.5	0.05	22	2	2	73	6.8	-0-	700	22.027
9-May-89	14	1	1.8	1.1	0.41	30	2	3.4	5.4	5.8	-0-	80	21.76
9-May-89	14	2	3.3	0.58	2.9	75	4.5	7.3	26	6.6	-0-	20	21.71
9-May-89	14	3	3.8	0.46	2.7	76	-0-	5.8	22	7	-0-	180	21.61
20-Jul-89	4	1	0.5	0.05	0.06	12	-0-	-0-	5.4	7.1	-0-	20	22.736
20-Jul-89	4	2	0.5	0.06	0.06	9.9	-0-	-0-	6	6.8	-0-	9	22.761
20-Jul-89	4	3	0.5	2.5	0.07	17	-0-	-0-	6	7.2	-0-	20	22.726
20-Jul-89	5	1	68	0.05	65	153	-0-	-0-	123	7.7	-0-	13	22.454
20-Jul-89	5	2	73	0.05	66	152	-0-	-0-	116	7.7	-0-	500	22.509
20-Jul-89	5	3	0.9	1.8	0.09	16	-0-	-0-	7.8	7	-0-	2	22.074
20-Jul-89	6	1	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	0	-0-	-0-
20-Jul-89	8	1	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	0	-0-	-0-
20-Jul-89	8	2	63	0.05	60	147	-0-	-0-	123	7.4	-0-	450	21.999
20-Jul-89	8	3	0.9	4.2	0.07	22	-0-	-0-	5.4	7.4	-0-	50	21.644
20-Jul-89	9	1	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	0	-0-	21.716
20-Jul-89	9	2	9	0.05	7.9	114	-0-	-0-	32	7.8	-0-	32	21.466
20-Jul-89	9	3	7	4.3	3.4	49	-0-	-0-	19	7.3	-0-	8	21.316
20-Jul-89	10	1	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	0	21.497
20-Jul-89	10	2	6	1.7	5.8	38	-0-	-0-	11	6.9	-0-	40	21.342
20-Jul-89	10	3	0.5	3.4	0.05	22	-0-	-0-	7.2	7	-0-	70	21.317
20-Jul-89	11	1	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	0	-0-	-0-
20-Jul-89	12	1	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	0	-0-	-0-
20-Jul-89	14	1	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	0	-0-	-0-
20-Jul-89	14	2	3.8	0.2	2.9	75	-0-	-0-	23	6.8	-0-	3	20.845
20-Jul-89	14	3	3	0.6	2.3	67	-0-	-0-	18	7	-0-	10	20.63
20-Jul-89	15	1	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	0	-0-	21.576
20-Jul-89	15	2	61	0.6	36	115	-0-	-0-	61	7.6	-0-	100	21.563
20-Jul-89	15	3	16	4	13	49	-0-	-0-	46	7	-0-	40	21.513
20-Jul-89	16	1	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	0	-0-	-0-
20-Jul-89	17	1	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	0	-0-	-0-
20-Jul-89	10A	1	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	0	-0-	-0-

-0- = not sampled

Appendix A

DATE	WELL	LEVEL	N-TKN	N-NO3	N-NH3	Cl	BOD	TOC	COD	pH	Coliforms		Head
											Fecal	Total	Meters
			mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l		/100 ml	/100 ml	A.S.L.
20-Jul-89	10A	2	16	0.05	16	99	-0-	-0-	45	7.2	-0-	0	21.035
20-Jul-89	10A	3	0.9	0.9	0.06	15	-0-	-0-	6.6	7.1	-0-	0	21.055
26-Oct-89	4	2	0.1	0.23	0.05	11	-0-	1.2	-0-	6.3	0	0	22.006
26-Oct-89	4	3	0.1	41.9	0.05	16	-0-	0.8	-0-	7.3	0	0	22.006
26-Oct-89	5	2	52	0.05	52	130	-0-	20	-0-	7.2	0	0	21.749
26-Oct-89	5	3	0.1	1.2	0.05	13	-0-	1.8	-0-	6.9	0	0	21.464
26-Oct-89	6	2	6.5	0.05	6.5	140	-0-	16	-0-	7.6	0	0	20.559
26-Oct-89	6	3	0.1	4	0.05	20	-0-	1.2	-0-	7.3	0	0	21.034
26-Oct-89	9	2	1.6	0.05	1.2	130	-0-	10	-0-	7.3	0	20	20.886
26-Oct-89	9	3	1.6	2.4	1.6	37	-0-	3.6	-0-	7.3	0	0	20.671
26-Oct-89	10	2	1.4	1.9	1.4	20	-0-	2.2	-0-	7	0	0	20.577
26-Oct-89	10	3	0.1	3.1	0.05	20	-0-	1.8	-0-	7.3	0	0	20.807
26-Oct-89	14	2	1.6	0.1	1.6	60	-0-	6.2	-0-	-0-	0	0	20.26
26-Oct-89	14	3	1.8	0.06	1.8	72	-0-	5.8	-0-	7.3	0	0	20.24
26-Oct-89	15	2	1.9	0.42	1.9	66	-0-	5.6	-0-	7.4	0	0	20.913
26-Oct-89	15	3	1.9	3.6	1.9	36	-0-	2.2	-0-	7.4	0	0	20.903
26-Oct-89	10A	2	5.7	0.05	5.7	96	-0-	11	-0-	7.2	0	0	20.677
26-Oct-89	10A	3	0.1	0.66	0.05	15	-0-	1.2	-0-	7.2	0	0	16.607
22-Nov-89	4	1	0.2	0.16	0.06	12	-0-	2.6	-0-	6.8	-0-	0	22.936
22-Nov-89	4	2	0.1	0.36	0.05	11	-0-	0.8	-0-	6.7	-0-	0	23.076
22-Nov-89	4	3	0.1	2.9	0.05	19	-0-	1	-0-	7.3	-0-	0	23.116
22-Nov-89	5	1	84	0.05	80	140	-0-	37	-0-	7.5	-0-	12	22.814
22-Nov-89	5	2	62	0.05	79	140	-0-	33	-0-	7.6	-0-	0	22.819
22-Nov-89	5	3	0.1	1.4	0.05	14	-0-	1.3	-0-	7.1	-0-	>1000	22.629
22-Nov-89	8	1	52	7.6	4.9	150	-0-	36	-0-	7.4	-0-	>1000	22.619
22-Nov-89	8	2	66	1	61	140	-0-	36	-0-	7.7	-0-	>1000	22.514
22-Nov-89	8	3	0.3	4.4	0.05	21	-0-	1	-0-	7.3	-0-	52	22.299
22-Nov-89	9	1	22	2.6	19	110	-0-	21	-0-	7.2	-0-	>1000	22.471
22-Nov-89	9	2	6.4	0.05	6.4	120	-0-	11	-0-	7.6	-0-	>1000	22.311
22-Nov-89	9	3	5	1.6	4.9	56	-0-	5.2	-0-	7.4	-0-	>1000	22.296
22-Nov-89	10	1	35	2.4	33	110	-0-	21	-0-	7.3	-0-	>1000	22.357
22-Nov-89	10	2	17.5	1.5	15	77	-0-	16	-0-	7.2	-0-	>1000	22.327
22-Nov-89	10	3	11.5	1.7	11.5	76	-0-	13	-0-	7.3	-0-	>1000	22.307
22-Nov-89	14	1	1	7.7	0.54	40	-0-	3	-0-	6.3	-0-	70	22.11
22-Nov-89	14	2	3.8	7.1	3.1	77	-0-	5.3	-0-	7.4	-0-	0	22.035
22-Nov-89	15	1	24.8	0.07	21	66	-0-	18	-0-	7.1	-0-	>1000	22.403
22-Nov-89	15	2	28.8	0.06	26	79	-0-	17	-0-	7.2	-0-	>1000	22.383
22-Nov-89	15	3	18.5	0.24	17	56	-0-	13	-0-	7	-0-	>1000	22.328
22-Nov-89	16	2	3.6	0.78	2.3	41	-0-	4.9	-0-	6.4	-0-	>1000	22.39
22-Nov-89	17	2	1	0.32	0.14	120	-0-	8.6	-0-	7.4	-0-	>1000	21.602
22-Nov-89	10A	1	15.2	0.29	13	81	-0-	17	-0-	6.6	-0-	>1000	22.152
22-Nov-89	10A	2	18.5	0.07	18	100	-0-	16	-0-	7	-0-	86	22.112
22-Nov-89	10A	3	0.4	0.4	0.07	33	-0-	2.6	-0-	7.2	-0-	140	20.092
24-Jan-90	4	1	1.5	0.14	1.3	14	-0-	2.5	-0-	6.8	-0-	120	22.826
24-Jan-90	4	2	0.1	0.29	0.05	11	-0-	0.5	-0-	6.3	-0-	1	23.026

-0- = not sampled

Appendix A

DATE	WELL	LEVEL	N-TKN	N-NO3	N-NH3	Cl	BOD	TOC	COD	pH	Coliforms		Head
											Fecal	Total	Meters
			mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l		/100 ml	/100 ml	A.S.L.
24-Jan-90	4	3	0.2	2.7	0.05	17	-0-	0.5	-0-	7.2	-0-	0	22.921
24-Jan-90	5	1	65	0.05	65	130	-0-	100	-0-	7.3	-0-	1	22.649
24-Jan-90	5	2	65	0.05	65	120	-0-	54	-0-	7.4	-0-	2	22.679
24-Jan-90	5	3	0.2	1.3	0.06	13	-0-	0.7	-0-	6.9	-0-	14	22.474
24-Jan-90	8	1	52	0.1	57	130	-0-	42	-0-	7.1	-0-	7100	22.409
24-Jan-90	8	2	52	0.05	52	130	-0-	34	-0-	7.3	-0-	200	22.304
24-Jan-90	8	3	0.3	3.6	0.05	20	-0-	0.9	-0-	7.4	-0-	2	22.109
24-Jan-90	9	1	12	9.6	12	100	-0-	11	-0-	7.4	-0-	800	22.206
24-Jan-90	9	2	8.2	0.05	7.8	86	-0-	9.7	-0-	7.4	-0-	13	21.936
24-Jan-90	9	3	4.3	1.9	3.6	41	-0-	4.6	-0-	6.5	-0-	2	21.746
24-Jan-90	10	1	28	2.6	28	94	-0-	16	-0-	7.3	-0-	510	22.057
24-Jan-90	10	2	21	1.6	21	80	-0-	13	-0-	7.2	-0-	40	21.967
24-Jan-90	10	3	1.7	3.2	1.3	34	-0-	3.6	-0-	7.3	-0-	60	21.962
24-Jan-90	12	2	20	3.3	18	78	-0-	15	-0-	7.6	-0-	71000	-0-
24-Jan-90	14	1	2.7	2.7	2.4	52	-0-	3.6	-0-	6.3	-0-	30	21.719
24-Jan-90	14	2	3.9	1.6	3.3	96	-0-	6.9	-0-	7.1	-0-	0	21.64
24-Jan-90	14	3	3.2	0.76	3.2	110	-0-	6.9	-0-	7.2	-0-	0	21.65
24-Jan-90	15	1	52.5	0.05	52	120	-0-	32	-0-	7.6	-0-	100	22.123
24-Jan-90	15	2	36	0.05	36	110	-0-	21	-0-	7.6	-0-	150	22.138
24-Jan-90	15	3	32.6	0.6	32	83	-0-	17	-0-	72	-0-	1300	22.133
24-Jan-90	16	2	1.5	2.4	0.77	40	-0-	3.5	-0-	7.2	-0-	660	22.18
24-Jan-90	17	2	1.2	0.05	0.16	120	-0-	9.8	-0-	7.7	-0-	310	21.997
24-Jan-90	10A	1	19	0.34	19	66	-0-	16	-0-	7	-0-	100	21.877
24-Jan-90	10A	2	17.6	0.13	17	92	-0-	16	-0-	7	-0-	50	21.882
24-Jan-90	10A	3	0.6	0.55	0.1	22	-0-	2.2	-0-	7.2	-0-	120	19.877
19-Apr-90	4	1	0.6	0.25	0.23	16	-0-	1.6	-0-	7.1	-0-	0	23.026
19-Apr-90	4	2	0.4	0.16	0.05	12	-0-	31	-0-	6.6	-0-	0	23.256
19-Apr-90	4	3	0.4	2.5	0.05	16	-0-	2.9	-0-	7.4	-0-	0	23.171
19-Apr-90	5	1	75	0.05	74	200	-0-	55	-0-	7.4	-0-	0	22.964
19-Apr-90	5	2	70.2	0.05	70	200	-0-	56	-0-	7.4	-0-	0	22.954
19-Apr-90	5	3	0.2	1.2	0.05	14	-0-	2.1	-0-	7.1	-0-	26	22.784
19-Apr-90	8	1	52	0.05	51	160	-0-	52	-0-	7.1	-0-	700	22.614
19-Apr-90	8	2	64	0.05	63	160	-0-	40	-0-	7.4	-0-	-0-	22.739
19-Apr-90	8	3	0.3	3.7	0.06	18	-0-	13	-0-	7.3	-0-	36	22.544
19-Apr-90	9	1	11.2	2.5	10	85	-0-	63	-0-	7.3	-0-	>1000	22.686
19-Apr-90	9	2	6.8	1.9	5.3	69	-0-	18	-0-	7	-0-	>1000	22.476
19-Apr-90	9	3	4.7	3.4	3.6	53	-0-	36	-0-	6.9	-0-	>1000	22.446
19-Apr-90	10	1	4.9	6.2	3.9	71	-0-	10	-0-	6.6	-0-	>1000	22.582
19-Apr-90	10	2	6.5	7.3	5.6	74	-0-	24	-0-	6.7	-0-	>1000	22.437
19-Apr-90	10	3	2.7	6.3	1.9	56	-0-	8.8	-0-	6.9	-0-	>1000	22.437
19-Apr-90	12	2	24	0.76	23	64	-0-	160	-0-	7.5	-0-	>1000	-0-
19-Apr-90	14	1	0.4	0.69	0.25	35	-0-	6.9	-0-	6.3	-0-	27	22.325
19-Apr-90	14	2	3.6	1.3	3	57	-0-	16	-0-	6.9	-0-	20	17.36
19-Apr-90	14	3	4.1	0.6	3.7	82	-0-	13	-0-	7	-0-	0	22.18
19-Apr-90	15	1	32.2	0.05	7	76	-0-	21	-0-	7.2	-0-	>1000	22.603

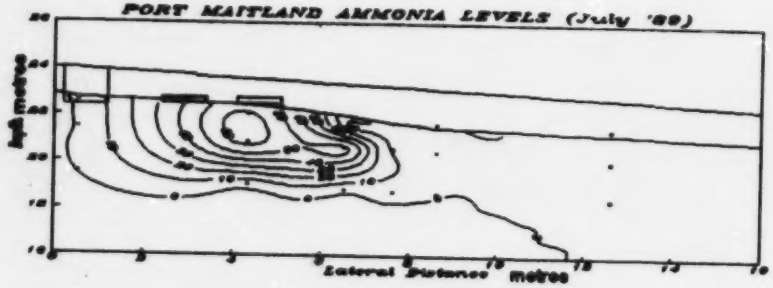
-0- = not sampled

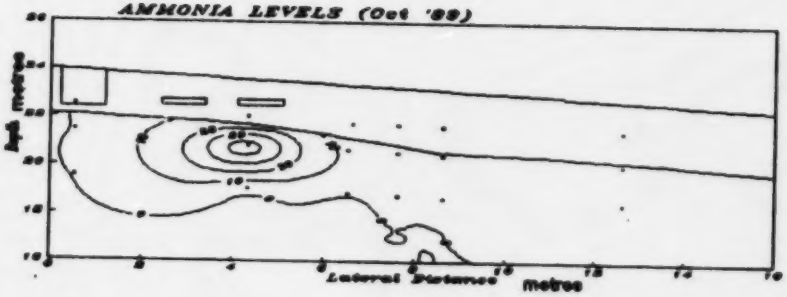
Appendix A

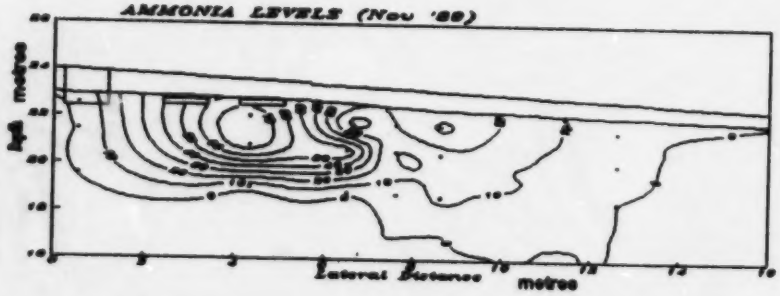
DATE	WELL	LEVEL	N-TKN	N-NO3	N-NH3	Cl	BOD	TOC	COD	pH	Coliforms		Head
											Fecal	Total	Meters
			mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l		/100 ml	/100 ml	A.S.L.
19-Apr-90	15	2	21	0.07	20	58	-0-	17	-0-	7.1	-0-	>1000	22.573
19-Apr-90	15	3	8.2	1.2	6.3	37	-0-	9	-0-	7	-0-	>1000	22.533
19-Apr-90	16	2	1.6	3.2	0.96	48	-0-	61	-0-	7.3	-0-	>1000	22.53
19-Apr-90	17	2	1	0.1	0.19	110	-0-	21	-0-	7.5	-0-	20	22.362
19-Apr-90	10A	1	15	4.1	14	76	-0-	21	-0-	6.8	-0-	>1000	22.292
19-Apr-90	10A	2	17	4.1	16	87	-0-	18	-0-	6.9	-0-	>1000	22.437
19-Apr-90	10A	3	0.9	3	0.31	36	-0-	5	-0-	7.2	-0-	>1000	20.242
6-Jun-90	4	1	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	22.961
6-Jun-90	4	2	0.5	0.12	0.05	11	-0-	5	-0-	-0-	-0-	0	23.141
6-Jun-90	4	3	0.2	2.4	0.05	16	-0-	2.8	-0-	-0-	-0-	0	23.061
6-Jun-90	5	1	61.9	0.1	61	150	-0-	103	-0-	-0-	-0-	5	22.834
6-Jun-90	5	2	62.3	0.07	62	160	-0-	73	-0-	-0-	-0-	0	22.839
6-Jun-90	5	3	0.2	1.4	0.05	14	-0-	6.5	-0-	-0-	-0-	0	22.649
6-Jun-90	8	1	16.1	6.2	15	96	-0-	17.1	-0-	-0-	-0-	>1000	22.624
6-Jun-90	8	2	6	0.4	5.4	61	-0-	15.2	-0-	-0-	-0-	>1000	22.509
6-Jun-90	8	3	2.7	2.2	2.3	31	-0-	5.7	-0-	-0-	-0-	>1000	22.429
6-Jun-90	9	1	63.3	0.05	63	190	-0-	53.5	-0-	-0-	-0-	15	22.486
6-Jun-90	9	2	63.3	0.05	63	180	-0-	28	-0-	-0-	-0-	20	22.296
6-Jun-90	9	3	0.3	4.1	0.05	20	-0-	5.1	-0-	-0-	-0-	5	22.251
6-Jun-90	10	1	15	6.4	15	89	-0-	12.6	-0-	-0-	-0-	>1000	22.367
6-Jun-90	10	2	10.8	3.2	10	67	-0-	17.4	-0-	-0-	-0-	>1000	22.227
6-Jun-90	10	3	1.6	3.1	0.77	26	-0-	99	-0-	-0-	-0-	>1000	22.217
6-Jun-90	11	2	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-
6-Jun-90	12	2	34	0.76	33	82	-0-	22.2	-0-	-0-	-0-	600	-0-
6-Jun-90	14	1	0.6	0.93	0.36	38	-0-	86.5	-0-	-0-	-0-	30	22.01
6-Jun-90	14	2	4.2	0.86	3.8	67	-0-	61	-0-	-0-	-0-	1	21.92
6-Jun-90	14	3	3.5	0.24	3.5	80	-0-	50	-0-	-0-	-0-	1	21.905
6-Jun-90	15	1	34.5	0.05	34	96	-0-	17.1	-0-	-0-	-0-	>1000	22.408
6-Jun-90	15	2	24.2	0.05	24	77	-0-	14.1	-0-	-0-	-0-	>1000	22.363
6-Jun-90	15	3	13.9	1.4	13	37	-0-	9.8	-0-	-0-	-0-	>1000	22.298
6-Jun-90	16	2	1.3	3.3	0.67	43	-0-	4.1	-0-	-0-	-0-	>1000	22.35
6-Jun-90	17	2	1	0.09	0.2	110	-0-	12.4	-0-	-0-	-0-	70	22.222
6-Jun-90	10A	1	13.4	4.3	12	77	-0-	18.3	-0-	-0-	-0-	>1000	22.057
6-Jun-90	10A	2	17.5	2.4	17	86	-0-	16	-0-	-0-	-0-	>1000	22.047
6-Jun-90	10A	3	1.2	1.1	0.74	25	-0-	3.6	-0-	-0-	-0-	>1000	20.037

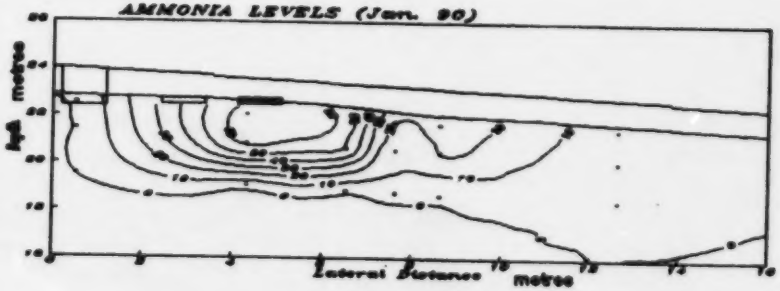
-0- = not sampled

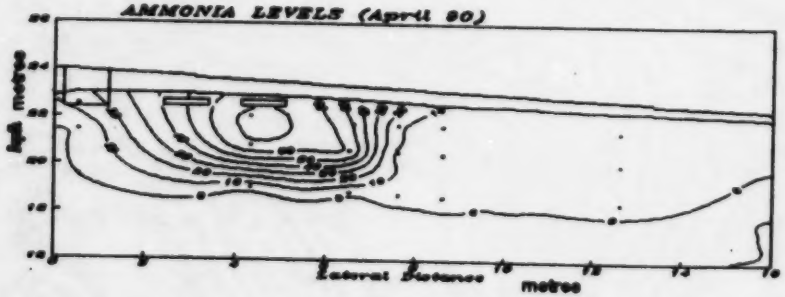
Appendix B: Ammonia Iso-Concentration Profiles

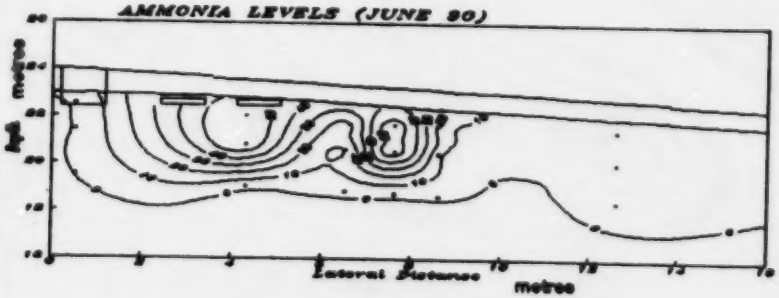




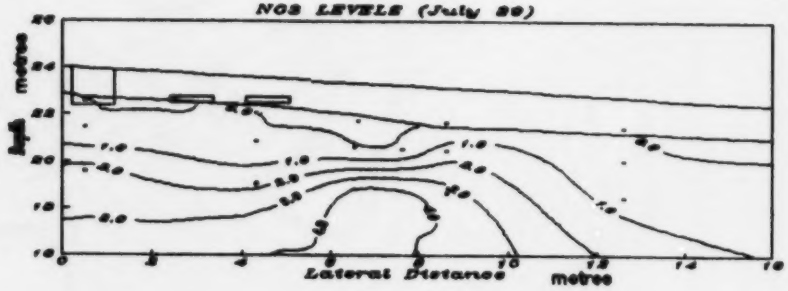


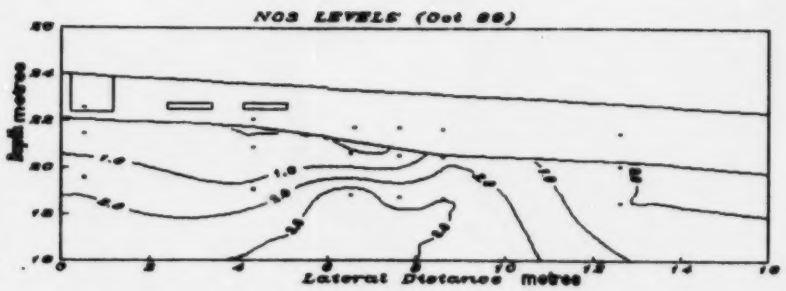


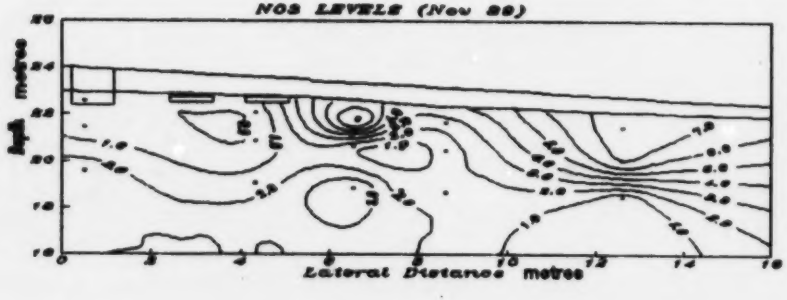


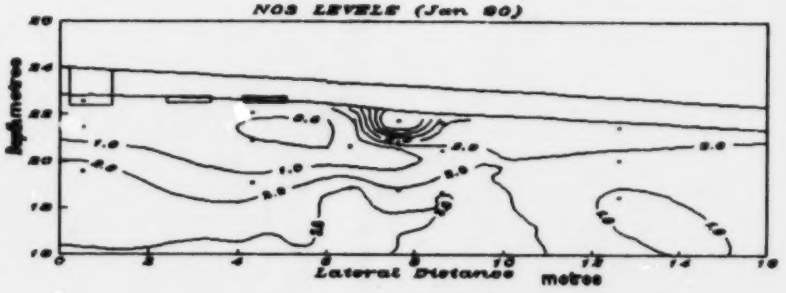


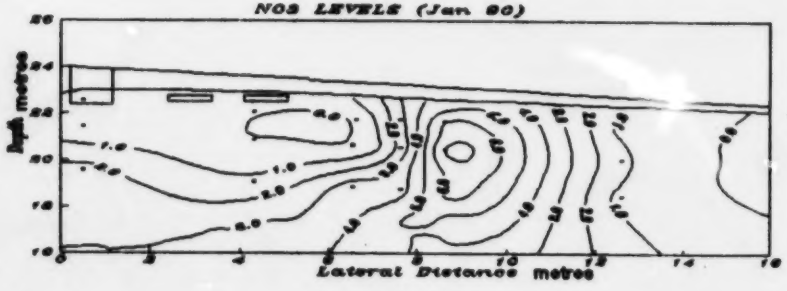
Appendix C : Nitrate Iso-Conentration Profiles

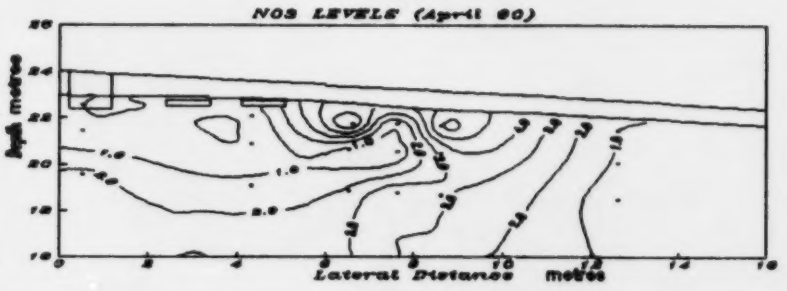




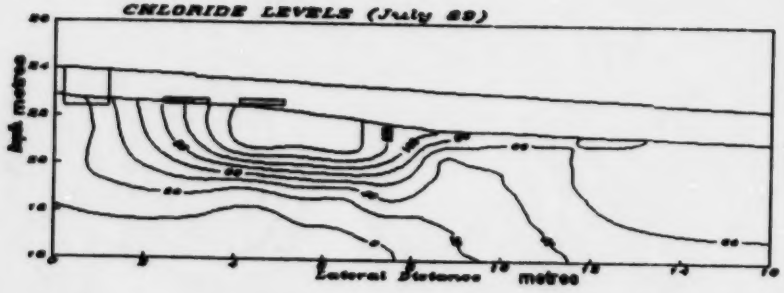


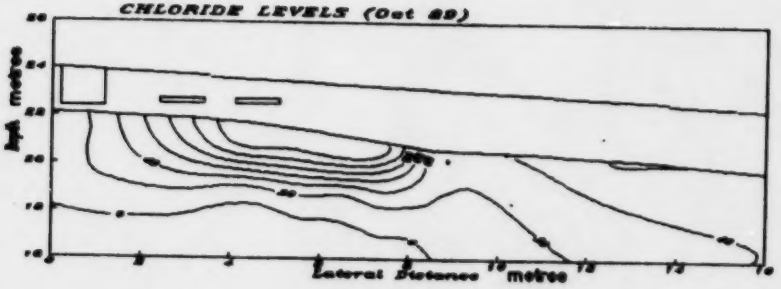


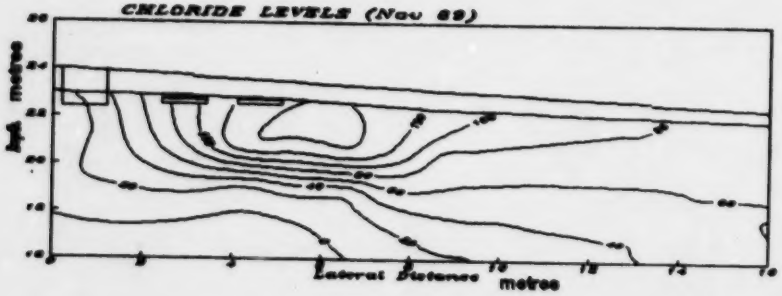


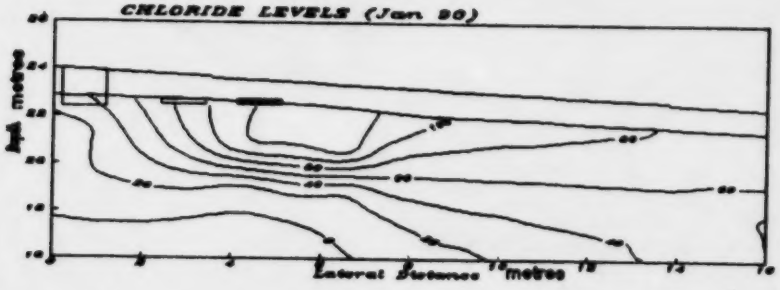


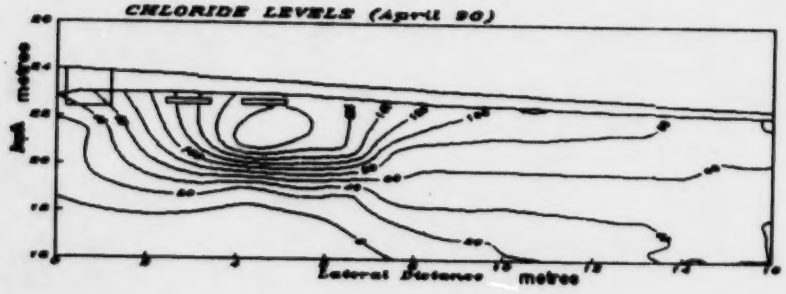
Appendix D: Chloride Iso-Concentration Fields

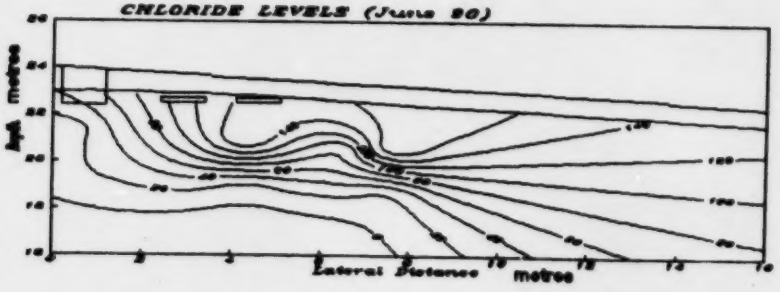




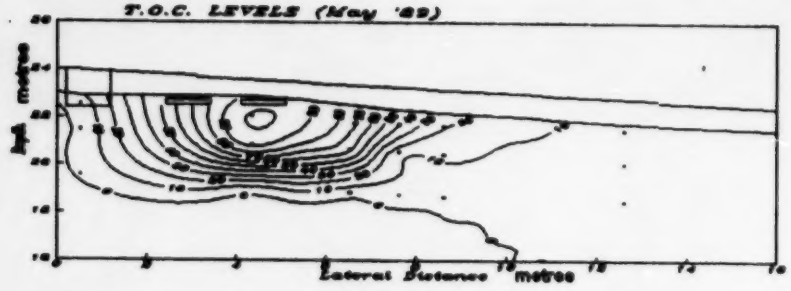


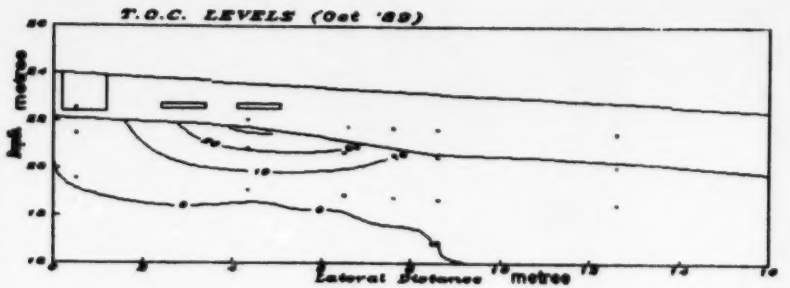


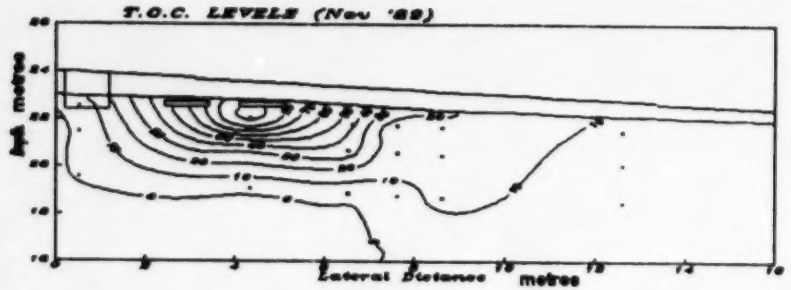


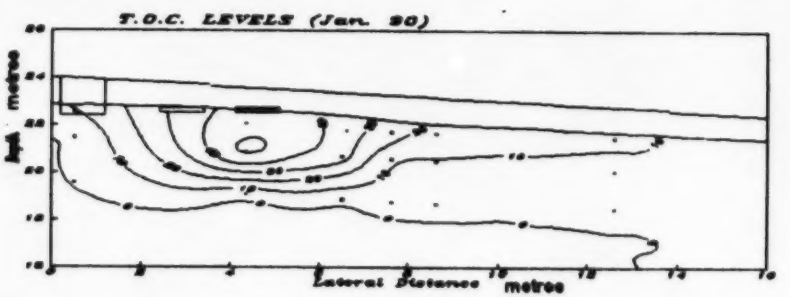


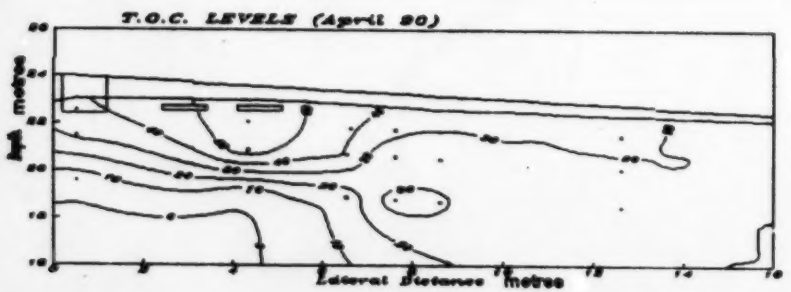
Appendix E: Total Organic Carbon Iso-Concentration Profiles

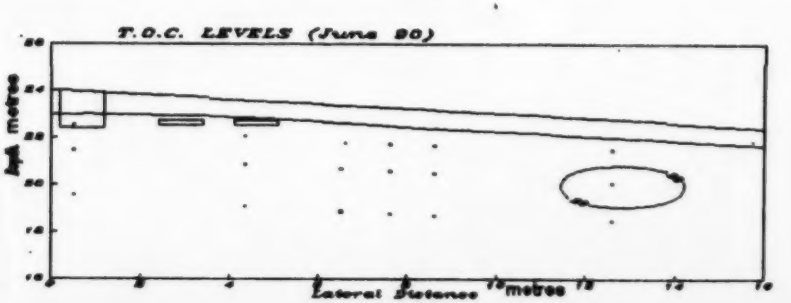












Appendix F: pH Iso-Concentration Profiles